Benthic TMDL Development:

Stressor Identification for Popes Head Creek, Virginia

Submitted to

Virginia Department of Environmental Quality

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1.0 Introduction

Total Maximum Daily Load (TMDL) development for biological impairment requires a methodology to identify impairment causes and to determine pollutant reductions that will allow streams to attain their designated uses. The identification of the pollutant(s), or *stressor(s)*, responsible for the impaired biological communities is an important first step in developing a TMDL that accurately specifies the pollutant load reductions necessary for the waterbody to comply with Virginia's water quality standards. This report details the steps used to identify and characterize the stressor(s) responsible for biological impairments in Popes Head Creek, Virginia. The first section of this report presents the regulatory guidance and defines the applicable water quality criteria for biological impairment. In the subsequent sections of this report, watershed and environmental monitoring data collected on Popes Head Creek are presented and discussed. Stressors which may be impacting the creek are then analyzed in the stressor identification section. Based on this analysis, candidate stressors impacting benthic invertebrate communities in the creek are identified. A TMDL will be developed for the stressor identified as the primary source of biological impairment in Popes Head Creek.

1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and instream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and

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Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and implement a more effective TMDL process. DEQ is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA, passed by the Virginia General Assembly in 1997), and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the Section 303(d) List of Impaired Waters. In addition to Section 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001). DEQ also solicits participation and comments from watershed stakeholders and the public throughout the TMDL process. Once TMDLs have been developed and the public comment period has been completed, the TMDLs are submitted to EPA for approval.

1.2 Impairment Listing

Popes Head Creek was initially listed on Virginia's 1998 Section 303(d) List of Impaired Waters (DEQ, 1998) and was subsequently included on Virginia's 2002 Section 303(d) List of Impaired Waters and in the 2004 Water Quality Assessment 305(b)/303(d) Integrated Report (DEQ, 2002; 2004) because of violations of the water quality standards for fecal coliform bacteria and the General Standard (benthic impairment). This report addresses the benthic impairment; the bacteria impairment will be addressed in a separate TMDL report. Biological assessments conducted at DEQ monitoring station

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1APOE002.00, located at the intersection of Popes Head Creek and Route 645, indicate an impaired benthic macroinvertebrate community, which resulted in the Section 303(d) listing.

Popes Head Creek is located in the northern region of Virginia, and is a tributary of Bull Run in the Occoquan Reservoir drainage. The headwaters of Popes Head Creek originate in the City of Fairfax; the remainder of the watershed is located in Fairfax County, Virginia. The impaired benthic segment of Popes Head Creek (VAN-A23R-02) is 4.92 miles in length, beginning at the confluence of Piney Branch and Popes Head Creek, and ending at the confluence of Popes Head Creek with Bull Run. **Figure 1-1** depicts the impaired segment of Popes Head Creek, as well as the delineated watershed boundary.

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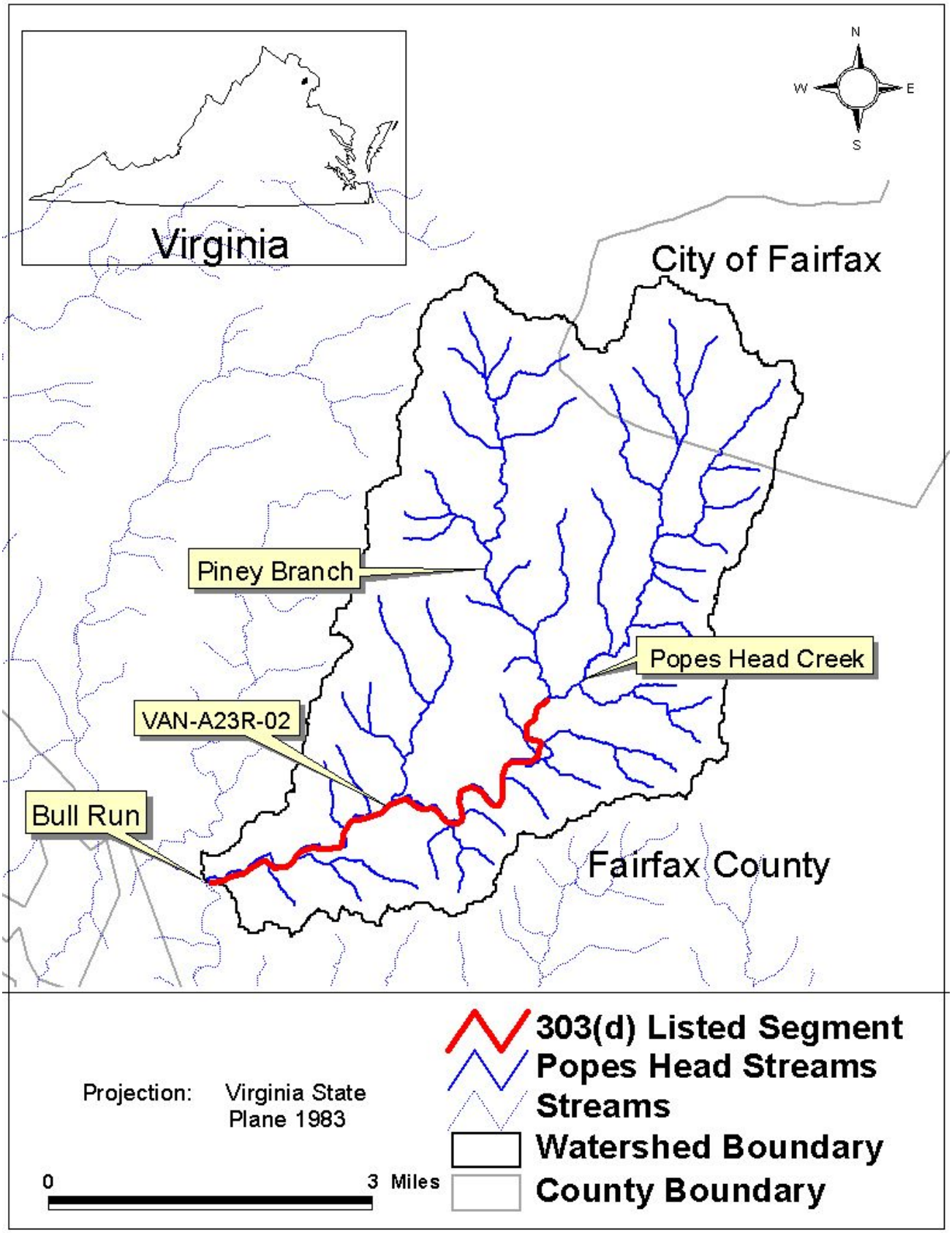

Figure 1-1: Popes Head Creek Impaired Segment and Delineated Watershed

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *water quality standards* "means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

The listed segment defined in Section 1.2 does not support the propagation and growth of aquatic life in Popes Head Creek, based on the biological assessment surveys conducted on the creek.

1.3.2 Water Quality Criteria

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

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The biological assessments conducted on Popes Head Creek indicate that some pollutant(s) are interfering with attainment of the General Standard, as impaired invertebrate communities have been observed in the listed segment of the creek. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

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2.0 Watershed Characterization

The physical conditions of Popes Head Creek were characterized using a geographic information system (GIS) developed for the watershed. The purpose of the characterization was to provide an overview of the conditions in the watershed related to the benthic impairment present in the listed segment of the creek. Information contained in the watershed GIS was used in the stressor identification analysis, as well as for the subsequent TMDL development. In particular, physical watershed features such as topography, soils types, and land use conditions were characterized. In addition, the number and location of permitted facilities and DEQ monitoring stations in the watershed were summarized.

2.1 Physical Characteristics

Important physical characteristics of the Popes Head Creek watershed that may be contributing to the benthic impairment were analyzed using GIS coverages developed for the area. GIS coverages for the watershed boundary, stream network, topography, soils, land use, and ecoregion of the watershed were compiled and analyzed.

2.1.1 Watershed Location and Boundary

The headwaters of the Popes Head Creek watershed flow through the western section of the City of Fairfax; the remainder of the Popes Head Creek watershed is located in Fairfax County, Virginia (**Figure 2-1**). The watershed is approximately 12,119 acres or 18.9 square miles. The impaired segment of Popes Head Creek is located entirely within Fairfax County.

2.1.2 Stream Network

The stream network for the Popes Head Creek watershed was obtained from the USGS National Hydrography Dataset (NHD). The stream network and benthic impairment segment are presented in **Figure 2-1**.

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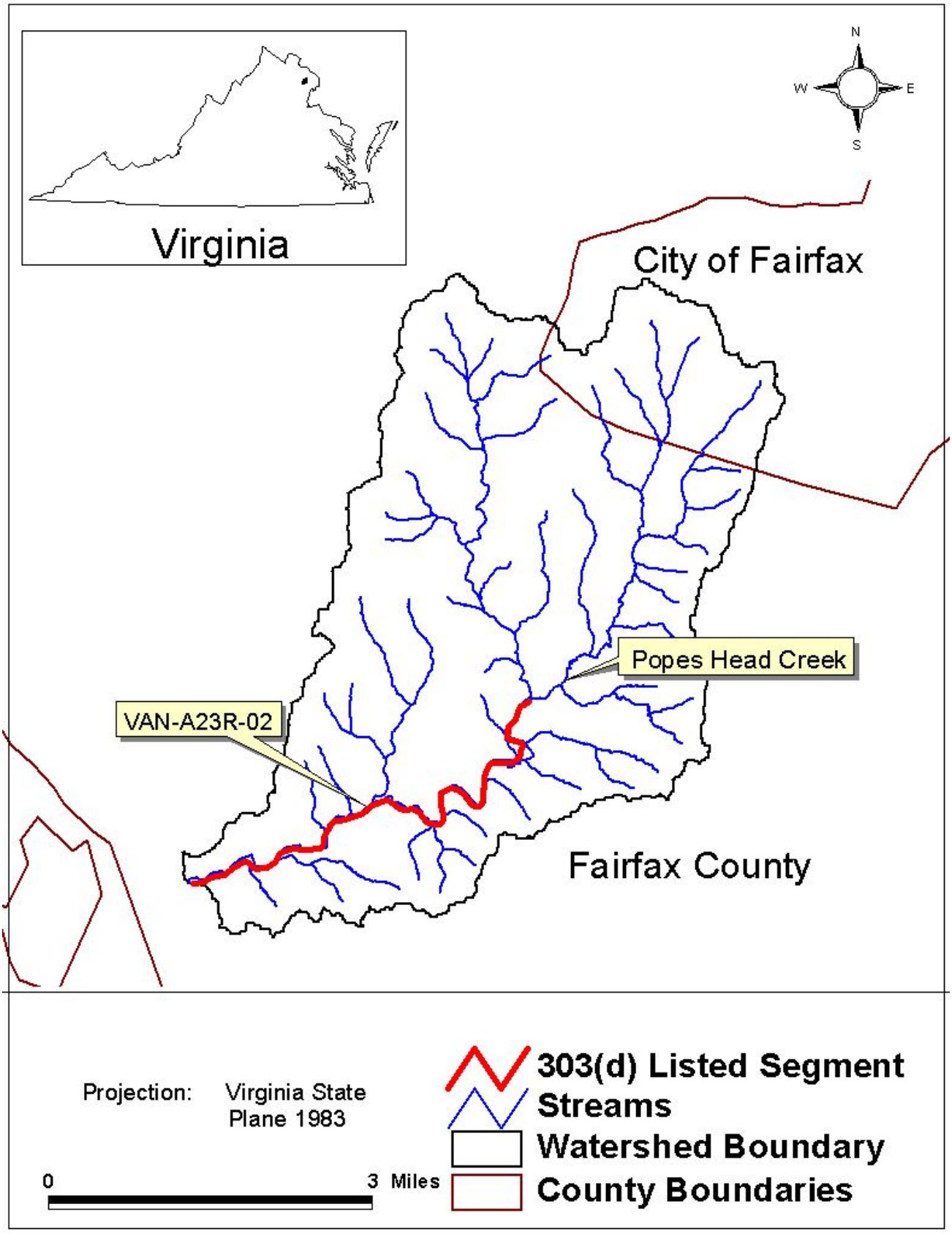

Figure 2-1: Stream Network for the Popes Head Creek Watershed

2.1.3 Topography

A digital elevation model (DEM) was used to characterize topography in the watershed. DEM data obtained from BASINS show that elevation in the watershed ranges from approximately 117 to 444 feet above mean sea level, with an average elevation of 309 feet above mean sea level.

2.1.4 Soils

The Popes Head Creek watershed soil characterization was based on the NRCS State Soil Geographic (STATSGO) Database for Virginia. There are three general soil associations present in the Popes Head Creek watershed; Buckhall-Occoquan-Meadowville, Jackland-Waxpool-Catlett, and Manor-Glenelg-Chester. The majority of soils in the watershed are comprised of the Manor-Glenelg-Chester soils association. The distribution of soils in the Popes Head Creek watershed, along with the hydrologic soil groups of each of the soils associations, is presented in **Table 2-1**.

Table 2-1: Soil Types in the Popes Head Creek Watershed

Map Unit ID	Soil Association	Percent	Hydrologic Soil Group
VA013	Buckhall-Occoquan-Meadowville	31.1	B
VA022	Jackland-Waxpool-Catlett	18.3	B/C/D
VA071	Manor-Glenelg-Chester	50.6	B/C/D

Source: State Soil Geographic (STATSGO) Database for Virginia

Hydrologic soil groups represent the different levels of soil infiltration capacity. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the groundwater system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the groundwater, resulting in more rainfall

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delivered to surface waters in the form of runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-2**.

Table 2-2: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

2.1.5 Land Use

The land use characterization for the Popes Head Creek watershed was based on land cover data from both the Northern Virginia Regional Commission (NVRC) 2000 Land Use Dataset, and the 1992 USGS National Land Cover Data (NLCD). The NVRC dataset was the most recent available land use dataset, and was also utilized in order to be consistent with other ongoing modeling efforts within the Occoquan Reservoir basin. However, the NVRC dataset does not specify forested or open (i.e., pasture) lands; therefore, the NLCD dataset was used to fill in the remaining areas. The distribution of land uses in the Popes Head Creek watershed, by land area and percentage, is presented in **Table 2-3**. Developed lands (56.9%), forested lands (36.9%), and agricultural lands (3.5%) represent the dominant land use types in the watershed. It should be noted that the majority of the developed lands present in the Popes Head Creek watershed are zoned for 2-acre or 4-acre lots, and thus are comprised of less impervious surfaces than typically observed developed areas. **Figure 2-2** displays a map of the land uses within the watershed.

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Table 2-3: Popes Head Creek Watershed Land Use Distribution

General Land Use Category	Specific Land Use Type	Acres	Percent of Watershed	Total Percent
Water/ Wetlands	Open Water	11.26	0.1	1.3
	Woody Wetlands	4.8	0.04	
	Emergent Herbaceous Wetlands	139.1	1.2	
Developed	Low Intensity Residential	4991.2	41.2	56.9
	Medium/High Intensity Residential	1420.4	11.7	
	Commercial/Industrial	263.9	2.2	
	Institutional	217.7	1.8	
Agriculture	Pasture/Hay/Livestock	407.4	3.4	3.5
	Row Crop	15.8	0.1	
Forest	Deciduous Forest	3696.7	30.5	36.9
	Evergreen Forest	352.3	2.9	
	Mixed Forest	426.6	3.5	
Other	Quarries/Strip Mines/Gravel Pits	0.8	0.01	1.4
	Transitional	13.9	0.1	
	Urban/Recreational Grasses	161.8	1.3	
Total		**12,119**	**100**	**100**

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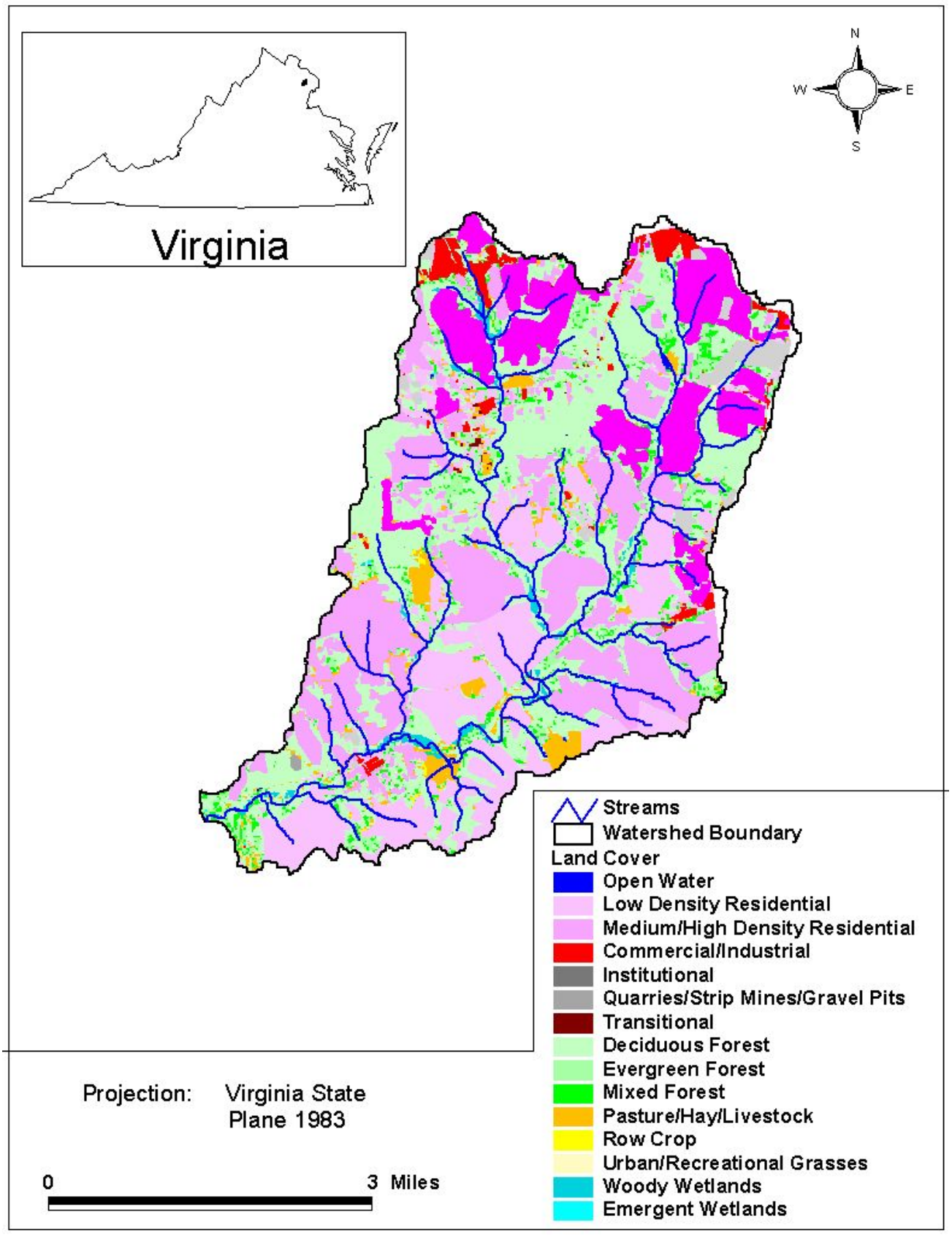

Figure 2-2: Land Use in the Popes Head Creek Watershed

2.1.6 Ecoregion Classification

The Popes Head Creek watershed straddles the Northern Piedmont ecoregion and the Piedmont ecoregion, USEPA Level III classification numbers 64 and 45, respectively (Woods et al., 1999). The location of the Popes Head Creek watershed within these ecoregions is presented in **Figure 2-3**. The Northern Piedmont ecoregion is a region of low rounded hills, irregular plains, and open valleys that serves as a transitional area between the low mountains to the north and west and the flat coastal plains to the east. Natural vegetation in the Northern Piedmont ecoregion is predominantly Appalachian oak forest, in contrast to the mostly oak-hickory-pine forests of the Piedmont ecoregion to the southwest.

The Piedmont ecoregion extends from Wayne County, Pennsylvania southwest through Virginia, and comprises a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

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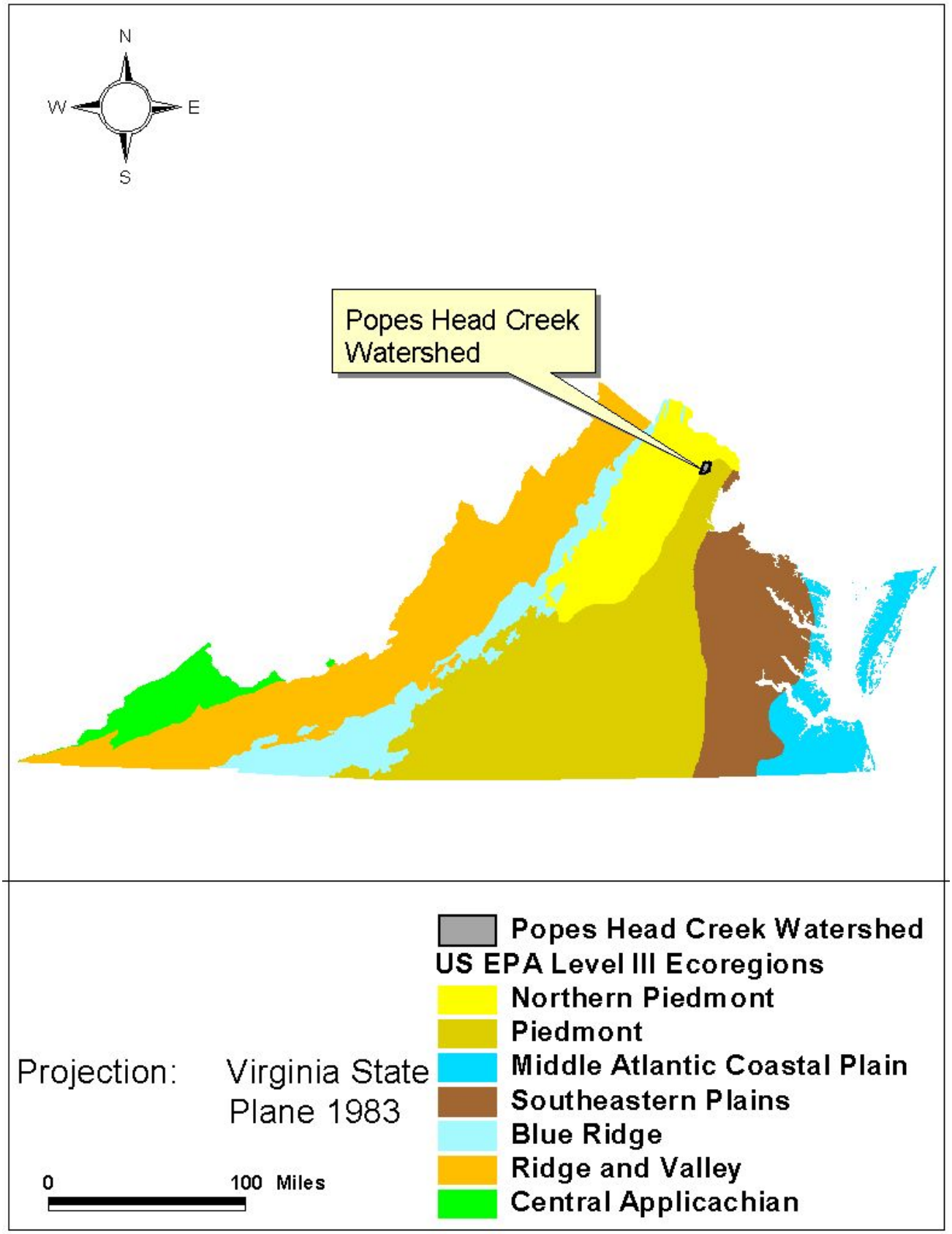

Figure 2-3: Virginia Level III Ecoregions

2.2 Permitted Discharge Facilities

There are no facilities holding active individual permits in the Popes Head Creek watershed. Based on information from DEQ, there are 2 active general permits in the Popes Head Creek watershed; 1 permit issued to a domestic sewage facility, and 1 stormwater permit issued to a construction site. Additional information on recent MS4 and general construction permits is forthcoming from DCR. The permit number, type, permitted flow, receiving waterbody, and status of each of the facilities holding general permits are presented in **Table 2-4**.

Table 2-4: General Permits Issued in the Popes Head Creek Watershed

Permit Number	Facility Name	Permit Type	Design Flow (gpd)[1]	Receiving Waterbody	Status
VAR104660	Chandler Grove	Stormwater Construction	-	Popes Head Creek	Active
VAG406252	Residence	Domestic Sewage	1,000	Popes Head Creek, UT	Active

Note: The information in this table is based on data from DEQ. Additional information on general permits is forthcoming from DCR.

2.3 DEQ Monitoring Stations

DEQ has several monitoring stations on Popes Head Creek which are used for biological and ambient water quality monitoring. A summary list of the DEQ monitoring stations located on Popes Head Creek is presented in **Table 2-5**, and the locations of these stations are presented in **Figure 2-4**. Station identification numbers include the abbreviated creek name and the river mile on that creek where the station is located. The river mile number represents the distance from the mouth of the creek.

Monitoring station 1APOE002.00 contained the longest and most recent ambient water quality data record, and thus was the primary source of water quality data used in the stressor identification and TMDL development. Biological monitoring data were also collected at station 1APOE002.00; Popes Head Creek was classified as impaired based on the results of bioassessment surveys conducted at this station. A detailed discussion of the available environmental monitoring data is presented in Section 3.0.

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Table 2-5: Summary of Monitoring Stations on Popes Head Creek

Station ID	Station Type	Period Of Record
1APOE001.55	Ambient Water Quality	1977-1988
1APOE002.00	Ambient and Biological	1990-2005
1APOE005.40	Ambient Water Quality	1977-1988
1APOE007.20	Ambient Water Quality	1988
1APOE008.36	Ambient Water Quality	1977-1988

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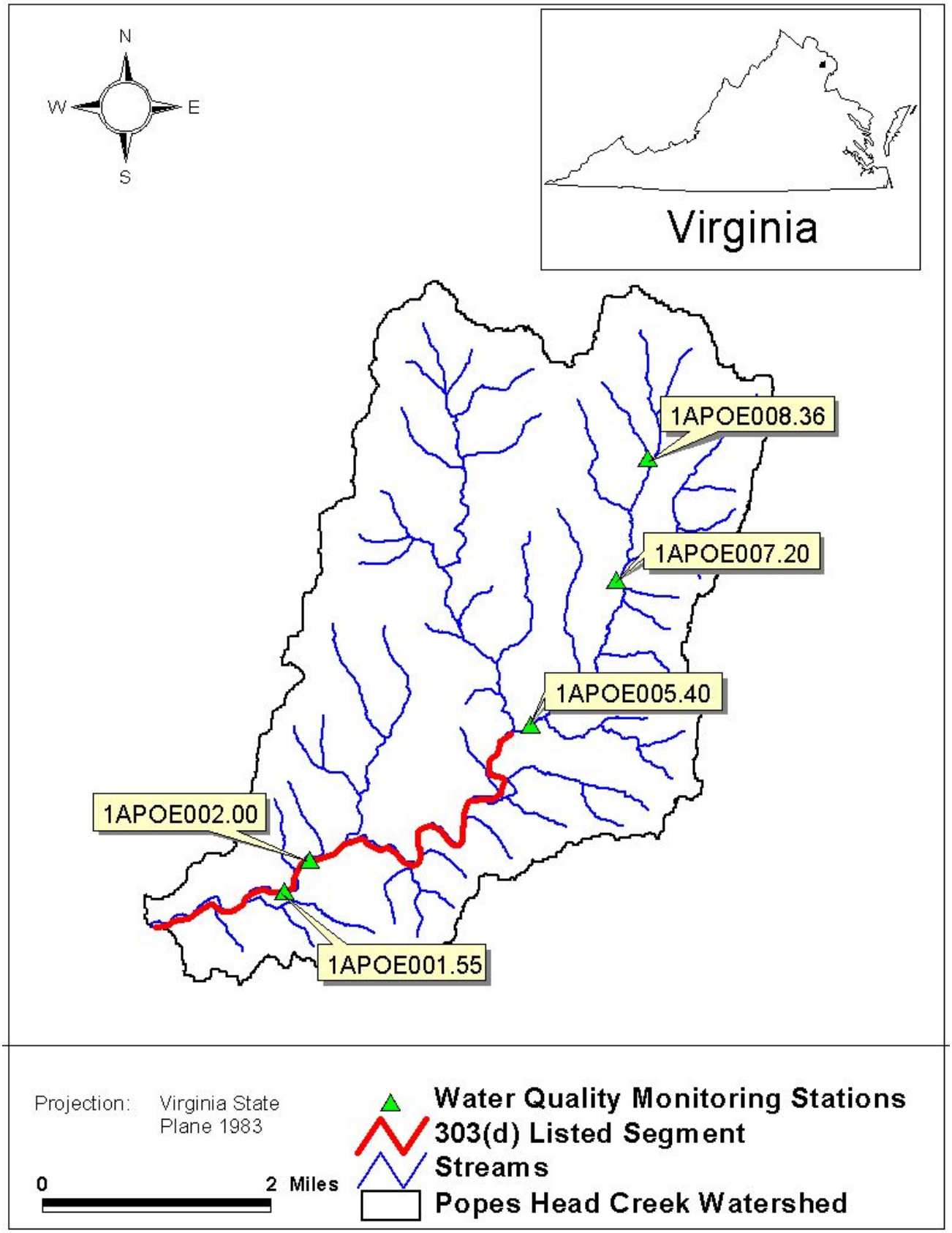

Figure 2-4: DEQ Monitoring Stations in the Popes Head Creek Watershed

2.4 Overview of the Popes Head Creek Watershed

Developed lands (56.9%), forested lands (36.9%), and agricultural lands (3.5%) represent the dominant land uses in the Popes Head Creek watershed. There are 2 facilities holding active general permits in the watershed, and no individual permitted facilities. Biological monitoring has been conducted by DEQ at station 1APOE002.00 on the biologically impaired segment of Popes Head Creek, and DEQ has collected ambient water quality data at five stations in the watershed. The land use and the locations of the monitoring stations in the watershed are shown in the summary map presented in **Figure 2-5**.

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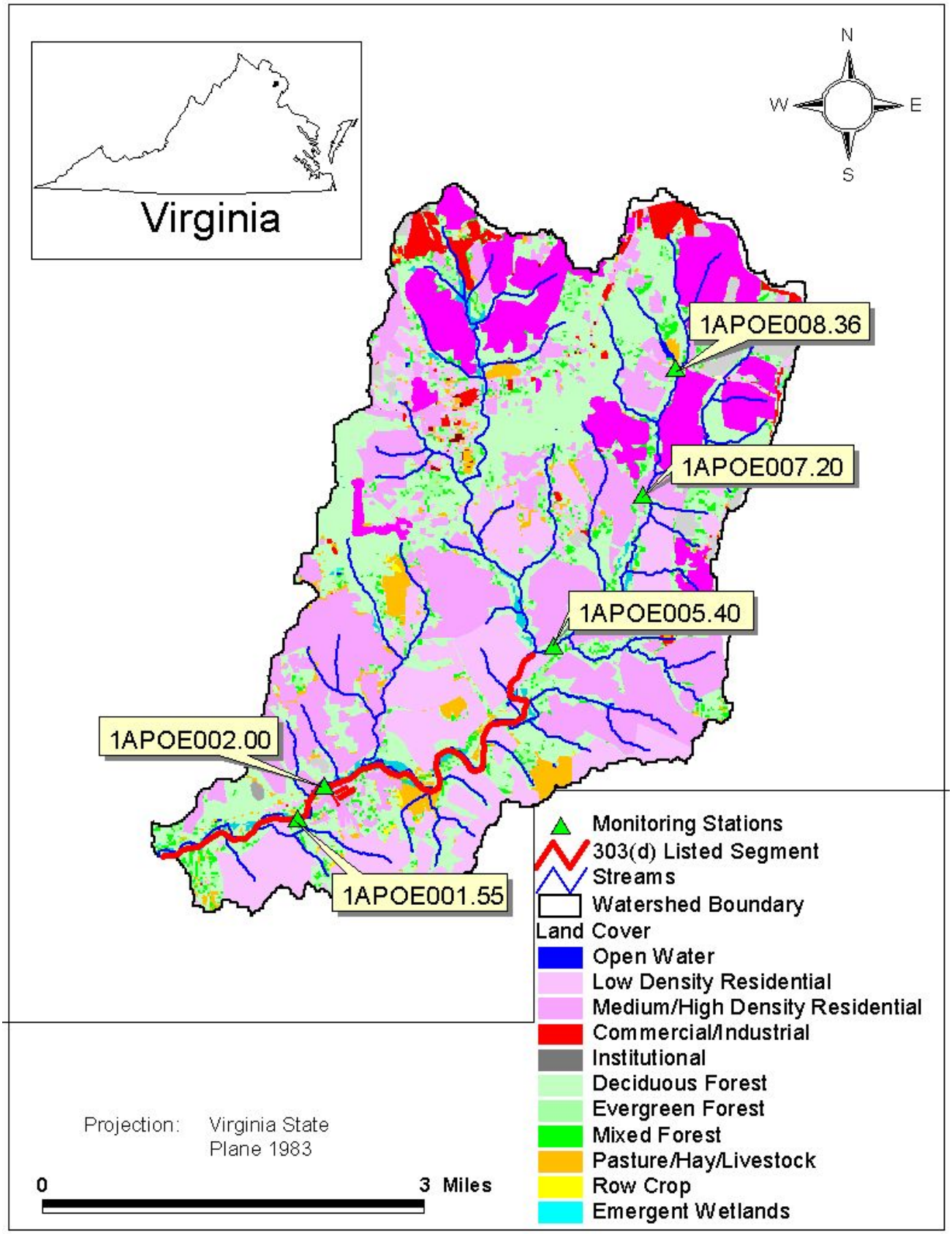

Figure 2-5: Overview of Popes Head Creek Watershed

3.0 Environmental Monitoring

Environmental monitoring efforts in the Popes Head watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, and toxicity testing. Monitoring efforts have been conducted by the Virginia Department of Environmental Quality (VADEQ), Fairfax County Stormwater Planning Division, and Audubon Naturalist Society (ANS), a citizen monitoring group. **Figure 3-1** plots the location of all monitoring locations in the Popes Head Creek watershed used for this analysis.

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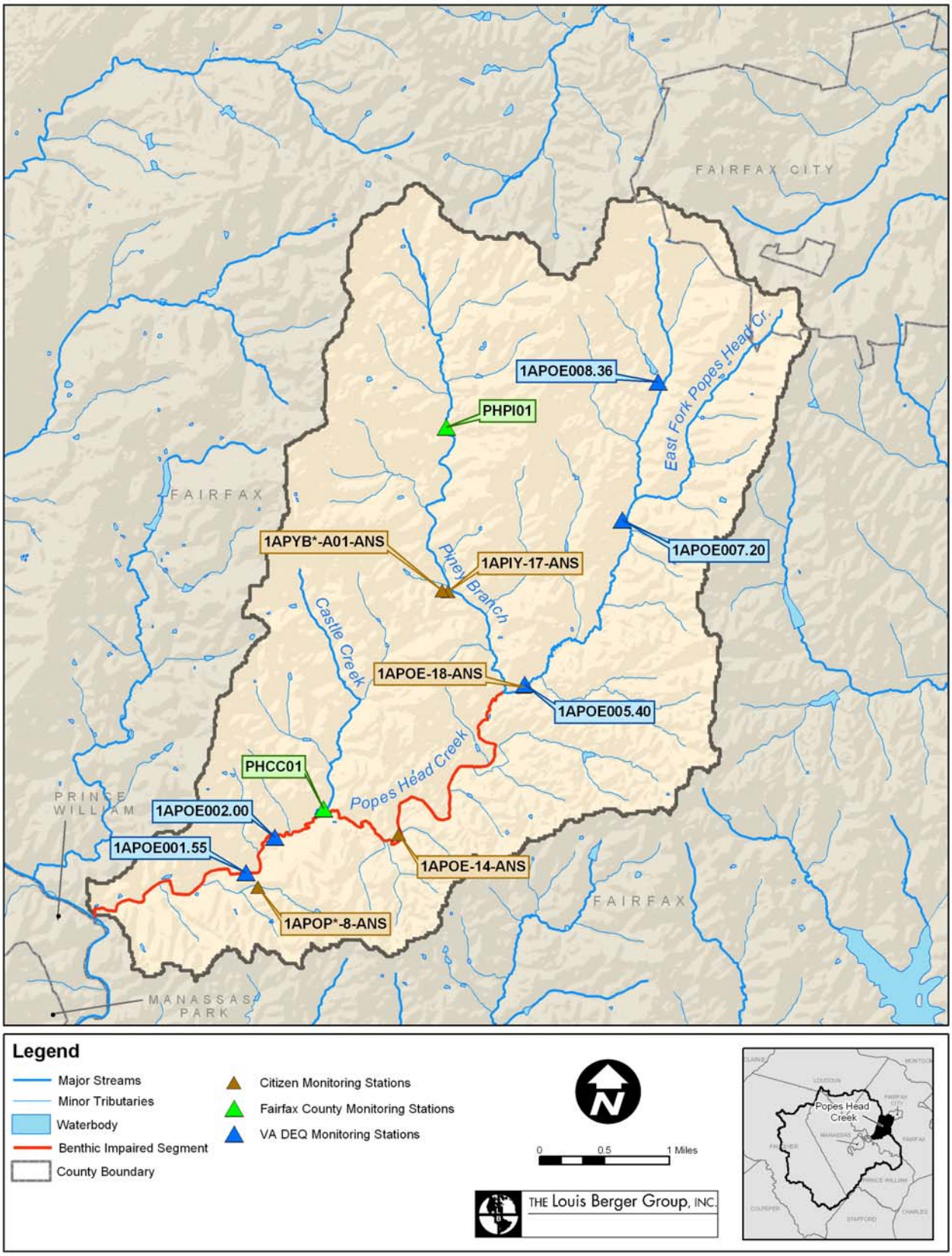

Figure 3-1. Monitoring Locations in the Popes Head Creek Watershed

3.1 Virginia Department of Environmental Quality Data

The first step in benthic TMDL development is the identification of the pollutant stressor(s) that is impacting the benthic community. Environmental monitoring data are vital to this initial step. The following sections summarize and present the available monitoring data used to determine the primary stressor impacting the biologically impaired segment of Popes Head Creek. Analyzed data included available biological and water quality monitoring data, and results from recent DEQ instream toxicity studies conducted on Popes Head Creek. The collection period, content, and monitored sites for these data are summarized in **Table 3-1**. The locations of the monitoring stations are presented in **Figure 3-1**. As stated previously in Section 2.0, no individual permitted facilities discharge into the Popes Head Creek watershed.

Table 3-1: Inventory of Environmental Monitoring Data for Popes Head Creek

Data Type	Collection Period	Monitoring Stations					
		1APOE001.55	1APOE002.00	1APOE005.40	1APOE007.20	1APOE008.36	Fairfax County Monitoring Stations
DEQ Biological Monitoring	1994-2004		X				
DEQ Ambient Water Quality Monitoring	1977-2004	X	X	X	X	X	
DEQ Field Water Quality Monitoring	1994-2004		X				
DEQ Toxicity Study	April 2004, May 2005		X				
Fairfax County Biological Monitoring	1999-2004						X

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3.1.1 Biological Monitoring Data

The impaired segment of Popes Head Creek was included on Virginia's 1998 Section 303(d) List of Impaired Waters and was subsequently included on Virginia's 2002 Section 303(d) List of Impaired Waters and in the 2004 Water Quality Assessment 305(b)/303(d) Integrated Report based on biomonitoring results obtained between 1997 and 2004.

RBPII Scores

A modified version of the EPA Rapid Bioassessment Protocols II (RBPII) was used to assess the biological condition of the river's benthic invertebrate communities. Candidate RBPII metrics, as specified in EPA's Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers, Second Edition (Barbour et al., 1999), are presented in **Table 3-2**. RBPII assessment ratings for the biomonitoring surveys conducted on Popes Head Creek are presented in **Table 3-3**.

Virginia DEQ bioassessments follow a paired reference approach using upstream stations located in the same watershed. The DEQ protocol uses eight standard metrics to compare monitored and reference sites. These metrics include taxa richness, composition, and tolerance/intolerance measures (**Table 3-2**).

DEQ field data sheets and bioassessment forms completed for each biological assessment conducted on Popes Head Creek contained the following information:

- Assessment ratings for each station for each survey event
- The numbers and types of macroinvertebrates present at each station
- Habitat assessment scores taken during each survey
- Field water quality data collected as part of each survey

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Table 3-2: Candidate RBPII Metrics Specified in Barbour et al. (2002)

Category	Metric	Definition	Response to Disturbance
Richness Measures	Total No. Taxa	Measures overall variety of invertebrate assemblage	Decrease
	No. EPT Taxa	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa	Decrease
	No. Ephemeroptera Taxa	Number of mayfly taxa	Decrease
	No. Plecoptera Taxa	Number of stonefly taxa	Decrease
	No. Trichoptera Taxa	Number of caddisfly taxa	Decrease
Composition Measures	% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae	Decrease
	% Ephemeroptera	Percent of mayfly nymphs	Decrease
Tolerance/ Intolerance Measures	No. Intolerant Taxa	Taxa richness of organisms considered to be sensitive to perturbation	Decrease
	% Tolerant Organisms	Percent of the macrobenthos considered to be tolerant of various types of perturbation	Increase
	% Dominant Taxon	Measures dominance of the most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa	Increase
Feeding Measures	% Filterers	Percent of the macrobenthos that filter FPOM from water column or sediment	Variable
	% Grazers and Scrapers	Percent of macrobenthos that scrape or graze upon periphyton	Decrease
Other Measures	Hilsenhoff Biotic Index	Uses tolerance values to weight abundance in an estimate of overall pollution	Increase

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Table 3-3: RBPII Assessment Ratings for Popes Head Creek Biomonitoring Surveys

Collection Period	Assessment Rating
	Station 1APOE002.00
Spring 1997	Moderate Impairment
Fall 1997	Moderate Impairment
Spring 1998	Moderate Impairment
Fall 1998	Moderate Impairment
Spring 1999	Slight Impairment
Fall 1999	Moderate Impairment
Spring 2000	Moderate Impairment
Spring 2004	Slight Impairment
Fall 2004	Slight Impairment
Spring 2005	Slight Impairment

Biomonitoring surveys were conducted biannually at 1APOE002.00 from 1997 to 2000, and then again in 2004 to the spring of 2005. During this period, the benthic community was consistently listed as impaired; 'moderately' for 6 out of 10 sampling events and 'slightly' for the remaining 4. Three RBPII metrics contributing to the overall impairment ratings consistently showed scores that were lower than those observed at the reference site. The first two, EPT to Chrionomidae abundance ratios (which compares the total number of mayflies, stoneflies, and most caddisflies which are mostly sensitive to pollution, to the number of midges, a predominantly tolerant family) and the EPT index (the total number of distinct taxa within the EPT groups), estimate the relative abundance of sensitive species present in the community and are therefore general indicators of water quality conditions. The last metric, the ratio of the shredder functional feeding group to the total number of individuals, is an indicator of riparian zone impacts and potential toxic effects.

Despite consistently impaired conditions, overall assessment ratings appeared to show a mild improvement during recent sampling events. Specifically, moderately impaired benthic communities were consistently observed at the beginning of the sampling record while more recent samples have indicated only slight impairment. Before 2000, RPBII scores were often more than 20 points lower than those recorded in 2004 and 2005. The

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EPT index was one metric that showed improvement during this period. Before 2001 the number of taxa within the EPT groups generally ranged between 2 and 4, but in 2004 and 2005 increased to between 5 and 7.

Although as a whole, most metrics improved in recent sampling events, some declined. For example, the MFBI (Modified Family Biotic Index) tended to be worse in recent samples. Values were frequently observed above 4.5, which may indicate organic pollution is affecting the benthic community. Additionally, the percent of dominant species in the sample was also notably higher than the percent observed at the reference site in recent sampling events. Though some of these changes may likely be related to rainfall variations over the past decade (drought conditions were observed in the pre-2000 sampling events) they are presented here for future reference and review until additional sampling data is available.

3.1.2 Virginia Stream Condition Index (SCI) Scores

Using the data collected during biomonitoring surveys, biological assessment scores were calculated using the Virginia Stream Condition Index (SCI) currently being developed by DEQ. The SCI is a regionally-calibrated index comprised of eight metrics that are listed in **Table 3-4**. The metrics used in calculation of an SCI score are similar to the metrics used in RBPII assessments. However, unlike RBPII, the reference condition of the SCI is based on an aggregate of reference sites within the region, rather than a single paired reference site. Therefore, SCI scores provide a measure of stream biological integrity on a regional basis. An impairment cutoff score of 61.3 has been proposed for assessing results obtained with the SCI. Streams that score greater than 61.3 are considered to be non-impaired, whereas streams that score less than 61.3 are considered impaired.

Calculated SCI scores for the biomonitoring station 1APOE002.00, located on Popes Head Creek, are presented in **Table 3-5**. SCI scores calculated for station 1APOE002.00 were, on average, below the proposed impairment cutoff score of 61.3; therefore, the station is considered to be impaired. Station 1ACAX004.57, located on Catoctin Creek, served as the reference station for the Popes Head Creek biological assessment from 1997

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to 2000. However, this monitoring station was discontinued as a reference site after 2000 due to a decline in the observed benthic community at this location. Station 1AGOO022.44, located on Goose Creek, served as the reference station for the biological assessments conducted on Popes Head Creek in 2004. Both of the reference stations had average SCI scores above the proposed impairment cutoff score.

Table 3-4: Metrics Used to Calculate the Virginia Stream Condition Index (SCI)

Candidate Metrics (by categories)	Expected Response to Disturbance	Definition of Metric
Taxonomic Richness		
Total Taxa	Decrease	Total number of taxa observed
EPT Taxa	Decrease	Total number of pollution sensitive Ephemoroptera, Plecoptera, and Trichoptera taxa observed
Taxonomic Composition		
% EPT Less Hydropsychidae	Decrease	% EPT taxa in samples, subtracting pollution-tolerant Hydropsychidae
% Ephemoroptera	Decrease	% Ephemoroptera taxa present in sample
% Chironomidae	Increase	% pollution-tolerant Chironomidae present
Balance/Diversity		
% Top 2 Dominant	Increase	% dominance of the 2 most abundant taxa
Tolerance		
HBI (Family level)	Increase	Hilsenhoff Biotic Index
Trophic		
% Scrapers	Decrease	% of scraper functional feeding group

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Table 3-5: Virginia SCI Scores for Popes Head Creek

Collection Period	SCI Score		
	1APOE002.00	1ACAX004.57[1]	1AGOO022.44[2]
Spring 1997	48.3	69.7	-
Fall 1997	56.2	74.8	-
Spring 1998	49.6	73.6	-
Fall 1998	56.4	68.7	-
Spring 1999	59.0	72.5	-
Fall 1999	48.2	70.5	-
Spring 2000	33.7	70.5	-
Fall 2000	-	68.0	-
Spring 2004	51.4	-	67.6
Fall 2004	48.2	-	62.6
Spring 2005	55.0		
Average	**50.6**	**71.1**	**65.1**

1: Monitoring station 1ACAX004.57 served as the reference station from 1994-2000
2: Monitoring station 1AGOO022.44 served as the reference station for 2004

3.1.3 Habitat Assessment Scores

A suite of habitat variables were visually inspected at station 1APOE002.00 as part of the DEQ biological assessments conducted on Popes Head Creek. Habitat parameters that were examined include channel alteration, sediment deposition, substrate embeddedness, riffle frequency, channel flow and velocity, stream bank stability and vegetation, and riparian zone vegetation. Each parameter was assigned a score from 0 to 20, with 20 indicating optimal conditions, and 0 indicating very poor conditions. Habitat assessment scores for the Popes Head Creek biomonitoring station, as well as the reference stations, are presented in **Table 3-6**.

Overall habitat assessment scores were generally lower at impaired station 1APOE002.00 than at the reference stations. Specifically, assessments scores for habitat metrics such as substrate embeddedness and riparian zone vegetation were, on average, lower at the impaired station than at the reference stations. Average assessment scores for other habitat metrics were generally similar between the reference and impaired stations.

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Table 3-6: Habitat Scores for Reference and Impaired Stations

Station ID	Date	Total Habitat Score	Channel Alteration	Bank Stability	Bank Vegetative Protection	Substrate Embeddedness	Channel Flow	Riffles	Riparian Vegetative Zone	Sediment Deposition	Velocity Regime
1APOE002.00	Spring 1997	158	17	18	17	12	18	18	12	15	17
	Fall 1997	166	17	18	17	14	19	18	12	16	18
	Spring 1998	161	17	16	17	14	18	15	14	16	17
	Fall 1998	157	18	17	17	12	18	14	15	15	15
	Spring 1999	165	18	18	17	14	18	16	15	16	16
	Fall 1999	168	18	17	18	14	18	18	15	16	18
	Spring 2000	164	19	18	17	14	19	18	14	15	14
	Spring 2004	149	19	16	10	14	18	17	11	14	17
	Fall 2004	155	20	17	14	14	17	17	11	14	15
	Average	**160.3**	**18.1**	**17.2**	**16.0**	**13.6**	**18.1**	**16.8**	**13.2**	**15.2**	**16.3**
1ACAX004.57	Spring 1997	180	19	17	17	18	19	18	17	18	19
	Spring 1998	177	19	18	18	17	18	17	17	17	17
	$Fall_1$ 1998	170	17	17	17	16	18	17	17	16	18
	$Fall_2$ 1998	176	18	17	18	19	18	17	17	18	16
	Spring 1999	179	18	18	18	18	19	18	17	17	18
	Fall 1999	163	18	17	17	14	19	17	16	10	18
	Spring 2000	164	18	15	17	15	19	16	15	14	18
	Fall 2000	165	18	14	16	17	18	17	16	16	16
	Average	**170.5**	**18.1**	**16.7**	**17.1**	**16.4**	**18.5**	**17.1**	**16.1**	**15.7**	**17.4**
1AGOO022.44	Spring 2004	174	19	17	19	16	18	16	19	16	17
	Fall 2004	176	20	18	18	16	18	16	19	15	19
	Average	**170.8**	**18.2**	**16.6**	**17.5**	**16.4**	**18.4**	**16.8**	**16.9**	**15.3**	**17.5**

3.1.4 Water Quality Monitoring

There are five DEQ ambient water quality monitoring stations located in the Popes Head Creek watershed. Information on each ambient monitoring station is summarized in **Table 3-7**. Monitoring station 1APOE002.00 represents the largest sources of water quality data available in the watershed, and the only station at which recent monitoring data are available.

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Table 3-7: Ambient Water Quality Monitoring Stations on Popes Head Creek

Station Id	Station Location	Period of Record	River Mile	No. Sampling events
1APOE001.55	Intersection with Route 659	1977-1988	1.55	2
1APOE002.00	Intersection with Route 645	1990-2004	2.00	78
1APOE005.40	Intersection with Route 660	1977-1988	5.40	2
1APOE007.20	Intersection with Route 654	1988	7.20	1
1APOE008.36	Intersection with Route 620	1977-1988	8.36	2

3.1.5 Instream Water Quality Data

Popes Head Creek is classified as a Class III waterbody (Nontidal Waters), as defined in Virginia Water Quality Standards (9 VAC 25-260-50). Thus, water quality parameters in the impaired segment must meet the Class III standards (**Table 3-8**).

Table 3-8: Virginia Water Quality Standards for Popes Head Creek

Class	Description of Waters	Dissolved Oxygen (mg/L)		pH	Maximum Temperature (Deg. C)
		Minimum	Daily Average		
III	Nontidal Waters	4.0	5.0	6.0-9.0	32

Instream water quality data collected on Popes Head Creek at station 1APOE002.00 from 1990 to 2004 are presented in **Figures 3-2** to **3-12**. The following is a bulleted summary of the monitoring data:

- Field dissolved oxygen, pH, and temperature values have been in compliance with numeric criteria for Class III waters (**Figures 3-2, 3-3, 3-5**).
- Biochemical oxygen demand concentrations at the station were low (**Figure 3-6**).
- Suspended solids concentrations were variable; observed concentrations were low for most sampling events, but elevated suspended solids concentrations were observed in some instances (**Figure 3-7**).

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- Nitrate, ammonia, and total phosphorus concentrations were generally low across all sampling events (**Figures 3-8** to **3-10**).

- Several violations of the Virginia fecal coliform instantaneous standard occurred at monitoring station 1APOE002.00 (**Figure 3-11**); a bacteria TMDL is currently being developed for Popes Head Creek and will be presented in a separate report.

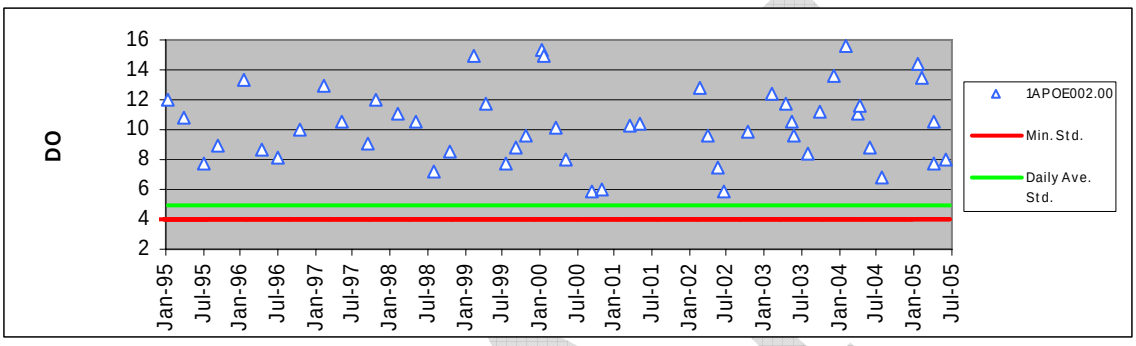

Figure 3-2: Popes Head Creek Field Dissolved Oxygen Concentrations

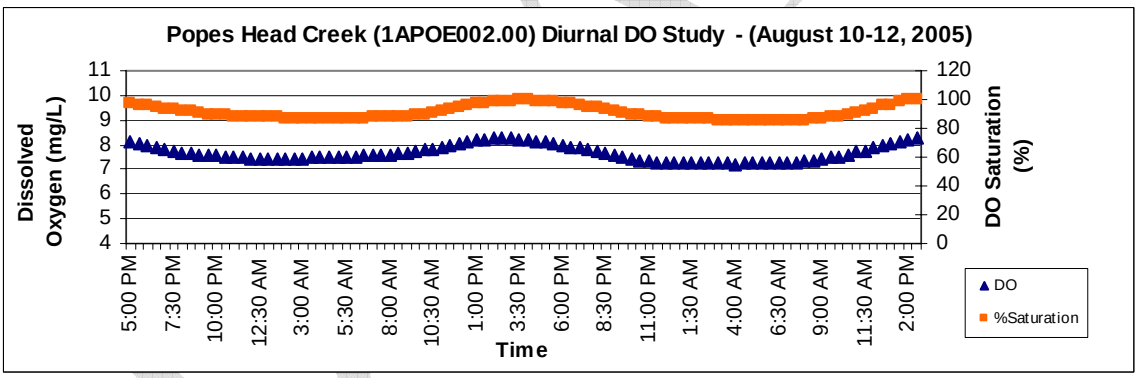

Figure 3-3: Popes Head Creek Diurnal DO Concentrations

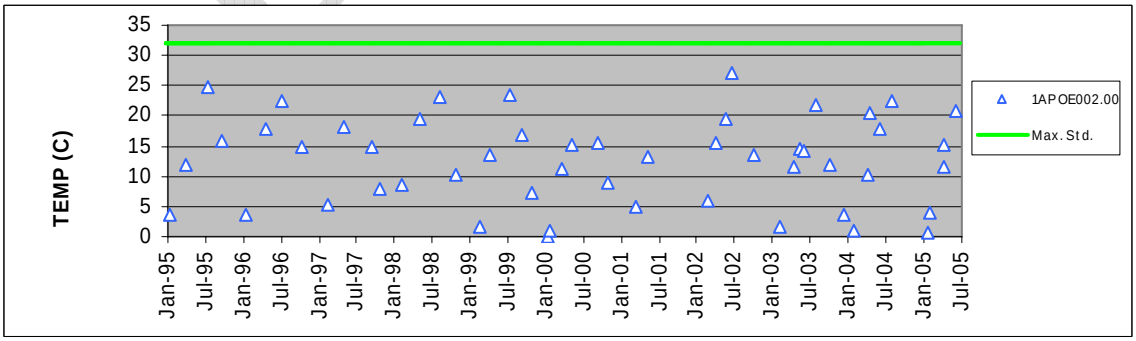

Figure 3-4: Popes Head Creek Field Temperature Data

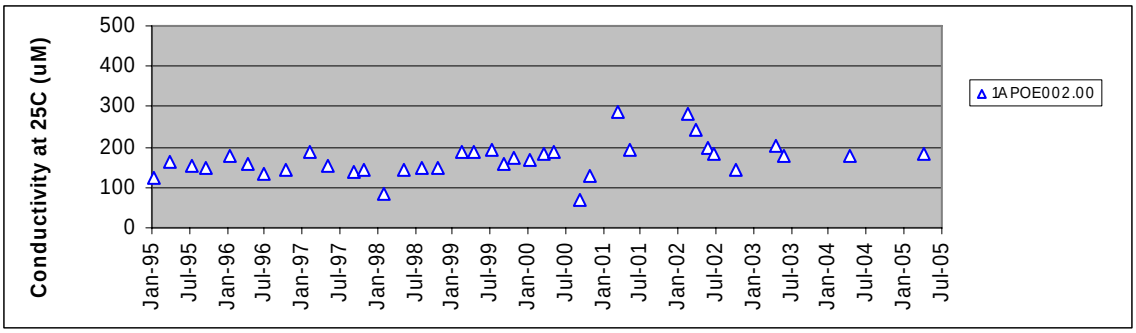

Figure 3-5: Popes Head Creek Conductivity Data

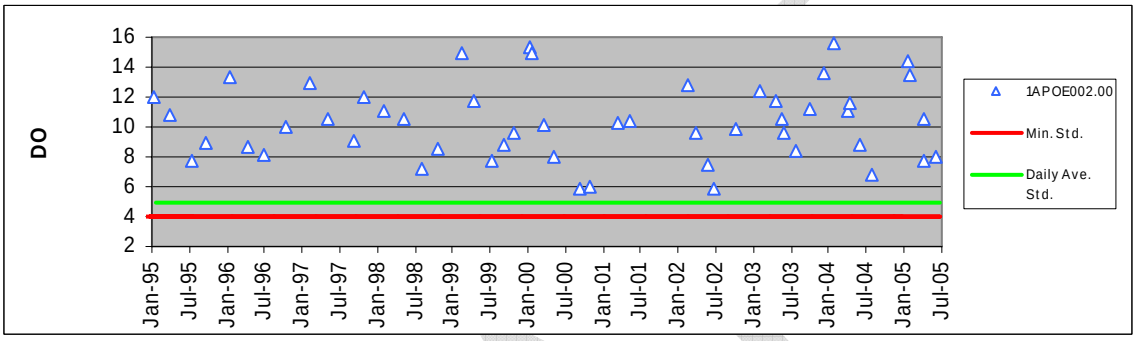

Figure 3-6: Popes Head Creek Field pH Data

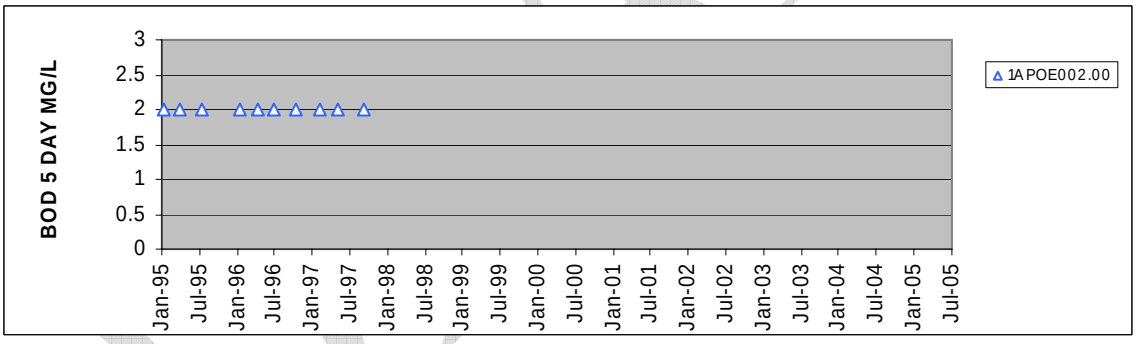

Figure 3-7: Popes Head Creek Biochemical Oxygen Demand Concentrations

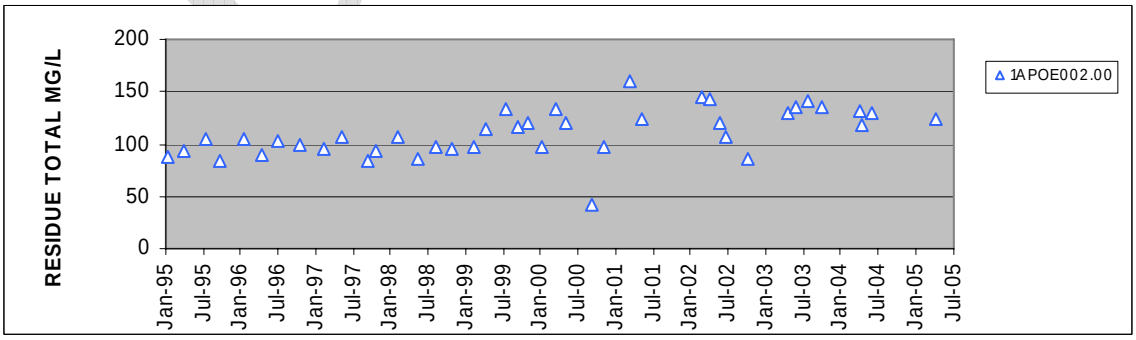

Figure 3-8: Popes Head Creek Suspended Solids Concentrations

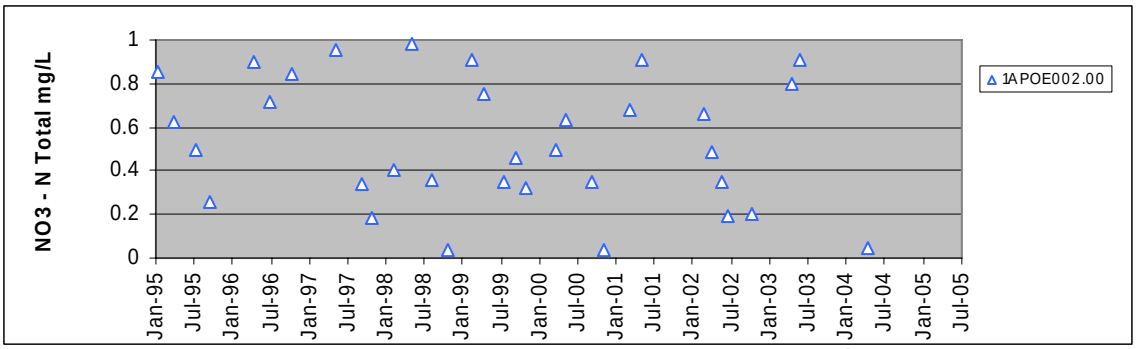

Figure 3-9: Popes Head Creek Nitrate Concentrations

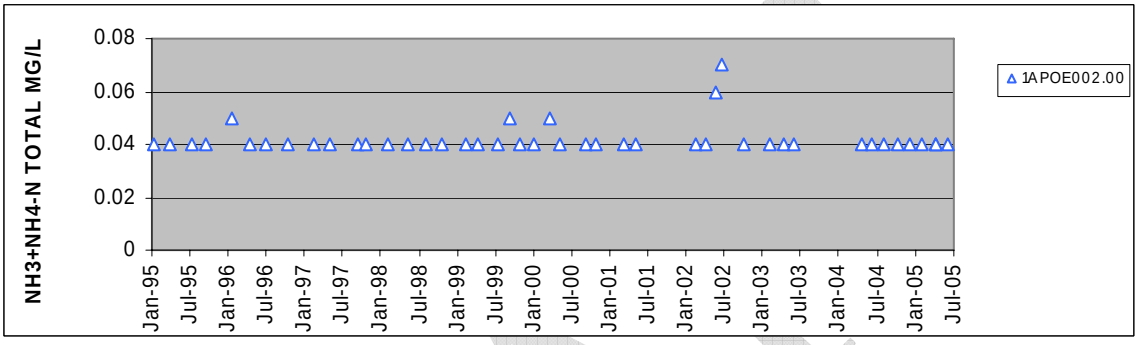

Figure 3-10: Popes Head Creek Ammonia Concentrations

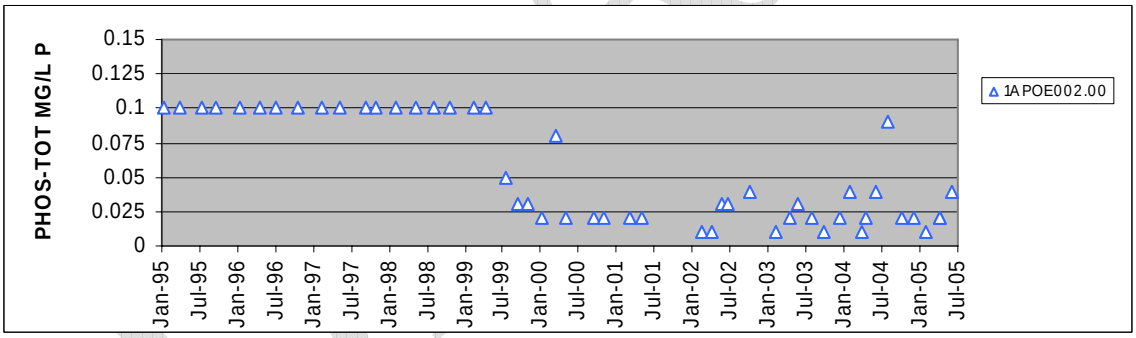

Figure 3-11: Popes Head Creek Total Phosphorus Concentrations

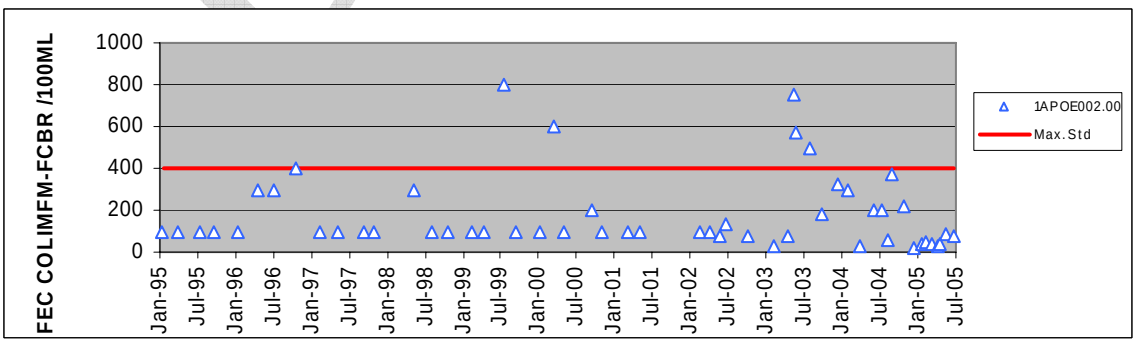

Figure 3-12: Popes Head Creek Fecal Coliform Concentrations

3.1.6 Metals Data

Both dissolved and sediment metals parameters were examined in Popes Head Creek, including arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc. All available dissolved metals data collected on Popes Head Creek were analyzed to determine whether the examined parameters complied with Virginia's established water quality standards. No monitored metals parameters violated acute or chronic dissolved freshwater criteria specified in Virginia's chronic or acute aquatic life use standards.

Additionally, although there are currently no water quality standards established for sediment metals, the 2004 DEQ assessment guidance memorandum (DEQ, 2004) establishes consensus based sediment screening values for use in determining aquatic life use support. The sediment metals data collected on Popes Head Creek were analyzed to determine whether they complied with the consensus based screening values. None of the available sediment metals data exceeded the sediment screening values specified in the DEQ 2004 assessment guidance memorandum.

3.1.7 Organics Data

Organics data collected on Popes Head Creek include dissolved and sediment samples analyzed for aldrin, dieldrin, endosulfan, endrin, dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyltrichloroethane (DDT), and PCBs. All available organics data collected on Popes Head Creek were analyzed to determine whether the examined parameters complied with Virginia's established water quality standards and sediment screening values. Organics concentrations were below detection limits for almost all of the samples analyzed. No monitored organics parameters exceeded acute or chronic dissolved freshwater criteria specified in Virginia's water quality standards. Additionally, none of the available sediment organics data exceeded the sediment screening values specified in the DEQ 2004 assessment guidance memorandum.

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3.1.8 Toxicity Testing

Toxicity testing was performed on water samples collected on Popes Head Creek by DEQ on April 12th, 14th, and 16th, 2004 and on May 2nd and 4th 2005 at station 1APOE002.00. The EPA Region 3 laboratory in Wheeling, West Virginia performed chronic toxicity testing on samples using fathead minnows and *Ceriodaphnia dubia* as test organisms.

Results on samples collected in 2004 indicated *Ceriodaphnia* mortality and reproduction in the Popes Head Creek water samples were statistically different than mortality and reproduction in the control samples, thus indicating that there were toxic water column effects to *Ceriodaphnia* in the Popes Head Creek samples. *Ceriodaphnia* survival in the Popes Head Creek samples was zero percent, as compared to 100 percent survival in the control samples. Fathead minnow growth in the Popes Head Creek water samples in 2004 was not statistically different from growth in the control samples. However, fathead minnow survival in samples collected at station 1APOE002.00 did significantly vary from minnow survival in the control samples. Minnow survival in samples collected at station 1APOE002.00 was 63 percent, which was statistically different from the laboratory control and provided further indication of toxicity in the Popes Head Creek water samples.

Additional samples were collected for toxicity testing by DEQ at station 1APOE002.00 on May 2nd and 4th, 2005. The EPA Region 3 laboratory in Wheeling, West Virginia performed chronic toxicity testing on these samples using the same protocol as described above. In contrast to results from samples taken in 2004, results from samples taken in May 2005 did not show any toxic effects on *Ceriodaphnia* mortality and reproduction. However, fathead minnow survival in samples collected at station 1APOE002.00 was approximately 60% percent, which was statistically different from the laboratory control. In addition, these samples also had a significant effect on the biomass of the fathead minnows which is further indication of toxicity in the Popes Head Creek water samples.

The EPA Region 3 laboratory in Wheeling, WV indicated that in their professional judgment, the difference in mortality rates between the samples taken at station

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1APOE002.00 and the control was "*probably biologically significant.*" In both instances, the EPA Region 3 laboratory emphasized that these results were qualitative in nature, and needed to be compared to other available water quality data.

3.2 Supplemental Monitoring Data

3.2.1 Fairfax County Biomonitoring Data

The Fairfax County Stormwater Planning Division Stream Protection Strategy (SPS) program conducted biomonitoring surveys in the Popes Head Creek watershed between 1999 and 2004. Fairfax County biological monitoring followed protocols similar to those used by the DEQ and uses the Virginia SCI method to calculate biological assessment scores for the sampled reaches (**Table 3-4)**. However, Fairfax County applies its own assessment rating terminology. The 'Impaired 1' assessment rating corresponds to a slight impairment, while the 'Impaired 2' assessment rating reflects a more severe impairment. The 'Reference' assessment rating indicates that the benthic invertebrate community collected at that site corresponds to a score above an SCI rating of 60. As indicated in **Table 3-9**, the Fairfax County SCI scores for Popes Head Creek were generally given the 'Impaired 1' or 'Impaired 2' assessment rating, and exceeded the cutoff of 60 on only one occasion. The results of the Fairfax County biological surveys were generally consistent with the DEQ biomonitoring results.

Table 3-9: Fairfax County SCI Scores for Popes Head Creek

Year	SCI Scores and Assessment Rating by Sample Station						
	PHCC01	PHPH01	PHPH02	PHPH03	PHPI01	PHPI02	PH0401
1999	**44.1** *Impaired 1*	**25.8** *Impaired 2*	**41.4** *Impaired 1*	**30.2** *Impaired 2*	**24.7** *Impaired 2*	**22.7** *Impaired 2*	NA
2001	**75.1** *Reference*	**41** *Impaired 1*	NA	NA	NA	NA	NA
2004	NA	NA	NA	NA	NA	NA	**22.6** *Impaired 2*

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3.2.2 Citizen Monitoring Data

Biological and habitat monitoring data was collected within the Bull Run Watershed by the Audubon Naturalist Society (ANS), a citizen monitoring group. ANS uses a modified version of the U. S. Environmental Protection Agency (EPA) Rapid Bioassessment II Protocol for macroinvertebrate collection and habitat assessment. Results obtained using the ANS methods are also used by DEQ for water quality assessments. A summary of ANS data is shown in **Table 3-10**.

Table 3-10: ANS Biological Monitoring Data

Station #	DEQ Site Number	Stream Name	Type	No. of Monitoring Events	Collection Peroid	Quality Rating
8	1APOP*-8-ANS	Unnamed tributary of Popes Head Ck	Biological, Habitat	17	1998-2002	Excellent
14	1APOE-14-ANS	Popes Head Creek	Biological, Habitat	14	1998-2002	Fair
17	1APIY-17-ANS	Piney Branch	Biological, Habitat	13	1999-2002	Fair
18	1APOE-18-ANS	Popes Head Creek	Biological, Habitat	8	2000-2002	Fair
A01	1APYB*-A01-ANS	Unnamed Tributary to Piney Branch	Biological, Habitat	1	1999	Poor
* "Overall Stream Quality Rating" - Cumulative rating based on all monitoring events						

Data summary

Both ANS stations located on Popes Head Creek ranked as fair. Station number 14 is located on the impaired segment and station number 18 is located above Popes Head Creek's confluence with Piney Branch (above the listed segment). Similarly, Piney Branch also ranked as fair, a ranking consistent with the impairment ranking (Impaired 2) reported by the Fairfax County Storm Water Planning Division's site upstream. The remaining two stations were located on small tributaries feeding the mainstem of either Popes Head or Piney Branch. These tributaries ranked excellent and poor (respectively), with the poor rating on the Piney Branch tributary presumably due to a lack of favorable habitat characteristics at this site.

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3.3 Permitted Facilities

As indicated in Section 2.0, there are no individual permitted facilities discharging into the Popes Head Creek watershed. There are two general permits present in the watershed (Table 2-4). The domestic sewage general permit is a minor discharger, which is not required to submit monthly discharge monitoring reports (DMR) to DEQ. The other general permit in the watershed is a stormwater construction permit issued to the Chandler Grove facility. This facility does not regularly discharge into Popes Head Creek or its tributaries, and thus is also not required to submit monthly DMR reports.

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4.0 Stressor Identification Analysis

TMDL development for benthic impairment requires identification of pollutant stressor(s) affecting the benthic macroinvertebrate community. Stressor identification for the biologically impaired segment of the Popes Head watershed was performed using the available environmental monitoring and watershed characterization data discussed in previous sections. The stressor identification follows guidelines outlined in the EPA Stressor Identification Guidance (EPA 2000).

The identification of the most probable cause of biological impairment in the Popes Head watershed was based on evaluations of candidate stressors that can potentially impact the river. The evaluation includes candidate stressors such as pH, temperature, dissolved oxygen, sediment, ammonia, flow modification, and toxic compounds. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Furthermore, potential stressors were classified as:

Non-stressors: The stressors with data indicating normal conditions and without water quality standard violations, or without any apparent impact

Possible stressors: The stressors with data indicating possible links, however, with inconclusive data to show direct impact on the benthic community

Most probable stressors: The stressors with the conclusive data linking them to the poorer benthic community. **Table 4.1** summarizes the results of the analysis.

Table 4.1: Summary of Stressor Identification in the Popes Head

Parameter	Location in Document
Non-Stressors	
Dissolved Oxygen	Section 4.1.1
Temperature and pH	Section 4.1.2
Metals	Section 4.1.3
Organics	Section 4.1.4
Possible Stressors	
Toxicity	Section 4.2.1
Most Probable Stressors	
Sedimentation and Urban Runoff	Section 4.3.1

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4.1 Non-Stressors

4.1.1. Dissolved Oxygen

Adequate dissolved oxygen (DO) levels are necessary for invertebrates and other aquatic organisms to survive in the benthic sediments of rivers or streams. Decreases in instream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. Field dissolved oxygen data presented in **Figure 3-2** indicates adequate DO levels in the Popes Head watershed. Similarly, the DO diurnal study conducted between August 10 and August 12, 2005 shows that DO levels remained above the minimum DO standards (**Figure 3-3**).

Consequently, Dissolved oxygen does not appear to be adversely impacting benthic communities in the Popes Head, therefore, it is classified as a non-stressor.

4.1.2. Temperature and pH

Benthic invertebrates require a suitable range of temperature and pH conditions. Although these ranges may vary by invertebrate phylogeny, high instream temperature values and either very high or very low pH values may result in a depauperate invertebrate assemblage comprised predominantly of tolerant organisms. The Virginia Class III water quality standards identify the acceptable pH and temperature ranges for the Popes Head. Field measurements indicated adequate temperature and pH values on and upstream of the biologically impaired segment (**Figures 3.4** and **3.6**). There have been no observed violations of Class III water quality standards for pH and temperature. Temperature and pH do not appear to be adversely impacting benthic communities in the Popes Head and are therefore classified as non-stressors.

4.1.3. Metals

All available dissolved metals data collected by VADEQ (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc) were below the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards. Additionally, the sediment metals data collected in the Popes Head watershed complied with the sediment screening values specified in the DEQ 2004 assessment guidance memorandum.

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Consequently, instream metals concentrations do not appear to be adversely impacting benthic communities in the Popes Head and are therefore classified as non-stressors.

4.1.4. Organic Chemicals

Dissolved organics parameters (aldrin, dieldrin, endosulfan, endrin, DDD, DDE, DDT, PAHs, and PCBs) did not exceed acute or chronic dissolved freshwater criteria specified in Virginia's water quality standards. Organics concentrations were below detection limits for almost all of the samples analyzed. Additionally, none of the available sediment organics data exceeded the sediment screening values specified in the DEQ 2004 assessment guidance memorandum.

Consequently, organic compounds do not appear to be affecting the benthic macroinvertebrates in the Popes Head, and are therefore classified as non-stressors.

4.2 Possible Stressors

4.2.1 Toxicity

Levels of ammonia, which is toxic to aquatic organisms in high concentrations, were low across all monitoring stations, and suggests that ammonia is not adversely impacting benthic invertebrates in the biologically impaired segments of the Popes Head watershed.

Instream toxicity testing was performed on water samples collected on Popes Head Creek by DEQ on April 12th, 14th, and 16th, 2004 and on May 2nd and 4th 2005 at station 1APOE002.00. The EPA Region 3 laboratory in Wheeling, West Virginia performed chronic toxicity testing on samples using fathead minnows and *Ceriodaphnia dubia* as test organisms.

As mentioned in Section 3.1.8, the EPA Region 3 laboratory in Wheeling, WV indicated that in their professional judgment, the difference in mortality rates between the samples taken at station 1APOE002.00 and the control was "*probably biologically significant.*" In both instances, the EPA Region 3 laboratory emphasized that these results were qualitative in nature, and needed to be compared to other available water quality data.

In summary, these toxicity testing suggest the presence of potential toxicity and are inconclusive to show a direct impact on the benthic community. Therefore, instream

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toxicity is considered as a possible stressor in the impaired segment of the Popes Head watershed.

4.3 Most Probable Stressors

4.3.1 Sedimentation and Urban Runoff

Excessive sediment loading can negatively impact benthic invertebrate communities by silting over invertebrate habitat, choking invertebrates with suspended sediment particles, and bringing invertebrates into contact with other pollutants that enter surface water via adhesion to sediment particles. In the Popes Head watershed, habitat assessment scores that show poorer substrate embeddedness scores in the impaired segment suggests the presence of increasing sediment loading (**Table 3-6**).

Additionally, the habitat metrics indicate a loss of riparian vegetation. (**Table 3-6**). The loss of riparian vegetation is usually caused by increased urbanization and impervious surfaces in the watershed, which leads to increased overland flow and channel erosion. Urban land uses comprise 59 percent of the watershed, further confirming the presence of higher runoff and stream bank erosion.

Consequently, the habitat assessment scores indicate that high runoff flows and stream bank erosion are the most probable stressors causing the habitat alterations in the Popes Head watershed.

4.4 Stressor Identification Summary

The data and analysis presented in this report indicate that dissolved oxygen, temperature, and pH, in the biologically impaired segment of Popes Head are adequate to support a healthy invertebrate community, and are not stressors contributing to the benthic impairment. Concentrations of metals and organic chemicals were generally low or below analytical detection limits and are classified as non-stressors. Toxicity testing suggest the presence of potential toxicity, however, the data are inconclusive to show a direct impact on the benthic community. Consequently, instream toxicity is considered as a possible stressor in the impaired segment of the Popes Head watershed.

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Based on the evidence and data discussed in the preceding sections, sedimentation, caused by higher runoff flows has been identified as a primary stressor impacting benthic invertebrates in the biologically impaired segments of the Popes Head. Habitat scores indicate decreased habitat quality in the impaired segments because of the surrounding urban environment. Potential sources of sediment loading in the watershed include urban stormwater runoff, stream bank erosion, and sediment loss from habitat degradation associated with urbanization.

The interrelation between sedimentation, higher runoff flows, and habitat alteration, allows a TMDL for sediments to address habitat degradation as well as increased urban runoff. Improvement of the benthic community in the biologically impaired segment of the Popes Head watershed is dependent upon reducing sediment loadings through stormwater control, as well as restoring instream and riparian habitat to alleviate the impacts of urbanization on the river.

Consequently and to address these issues, a sediment TMDL will be developed for the biologically impaired segment of the Popes Head watershed.

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